14th The Applied Antineutrino Physics (APP) workshop

The Development of Low Threshold Dual Phase Argon Detector for CEνNS

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On Behalf of Dual Phase Argon Working Group
(IHEP BISEE etc.…)

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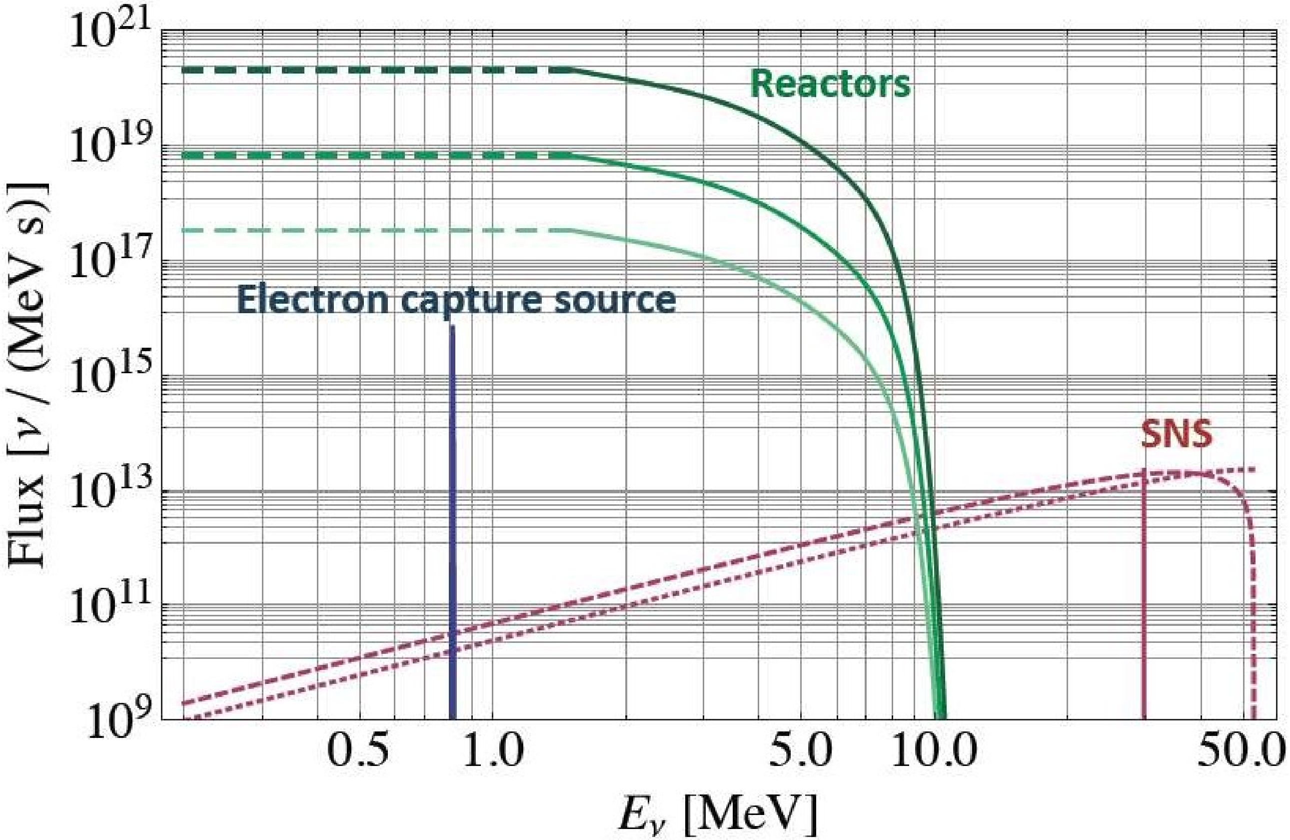
Outline

- The CEνNs Process
- The Development of Dual Phase Argon Detector
- The Future Plan for TaiShan Power Plant Test

Two Ways to CEνNS Process Measurement



Low energy ν's from accelerators:

π-decay-at-rest (DAR) ν source

Different flavors produced

relatively high recoil energies

➔ close to de-coherence

Reactors:

Lower ν energies than accelerators

Lower cross section

Different flavor content

implications for probes of new physics

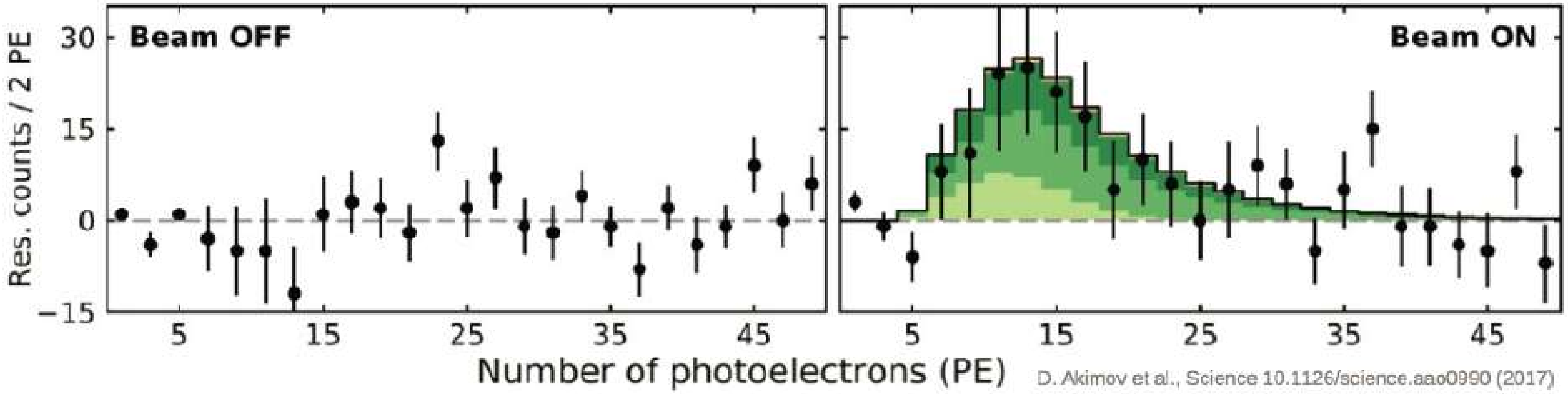
Results from SNS Source

COHERENT experiment (stopped π beam 30-50 MeV neutrinos)

- 4 different detector technologies
  - 14 kg of **CsI** scintillating crystals
  - 35 kg single phase LAr detector
  - 185 kg NaI scintillating crystal
  - 10 kg HPGe PPC detectors
- SNS source with $\bar{\nu}$ flux of $4.3 \cdot 10^7$ $\nu/cm^2/s$ @ 20m

First COHERENT result July 2017

- 15 month of live-time accumulated with CsI[Na]
- 6.7 σ significance for excess in events, with 1 σ consistency with the SM prediction



D. Akimov et al., Science 10.1126/science.aao0990 (2017)

Some Reactor Experiments

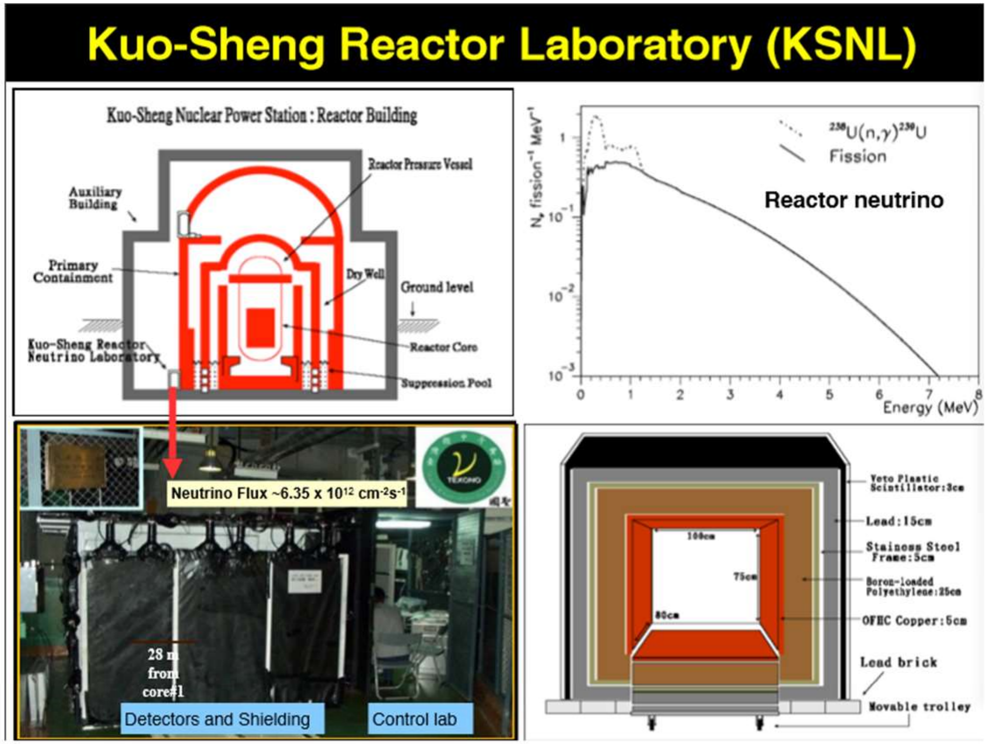
Combine:

- **highest neutrino flux ➔ close to power reactor**
- **lowest detection threshold ➔ R&D**
- **best background supression ➔ "virtual depth"**

Rate comparison (all detectors):

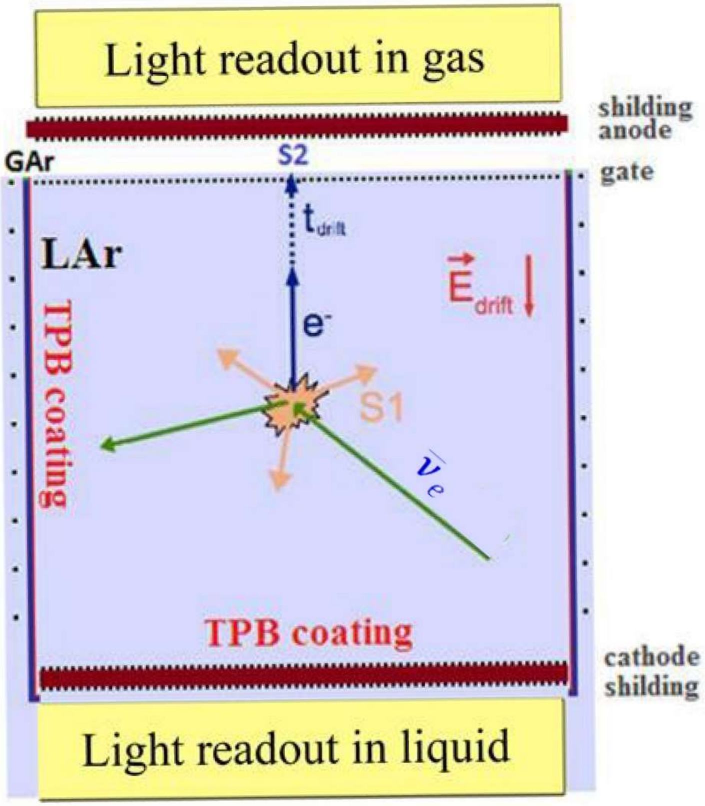
	counts	counts/(d·kg) (*)
reactor OFF (114 kg*d)	582	
reactor ON (112 kg*d)	653	
ON-OFF (exposure corr.)	84	0.94
Significance	2.4 σ	2.3 σ

Some systematics still under study

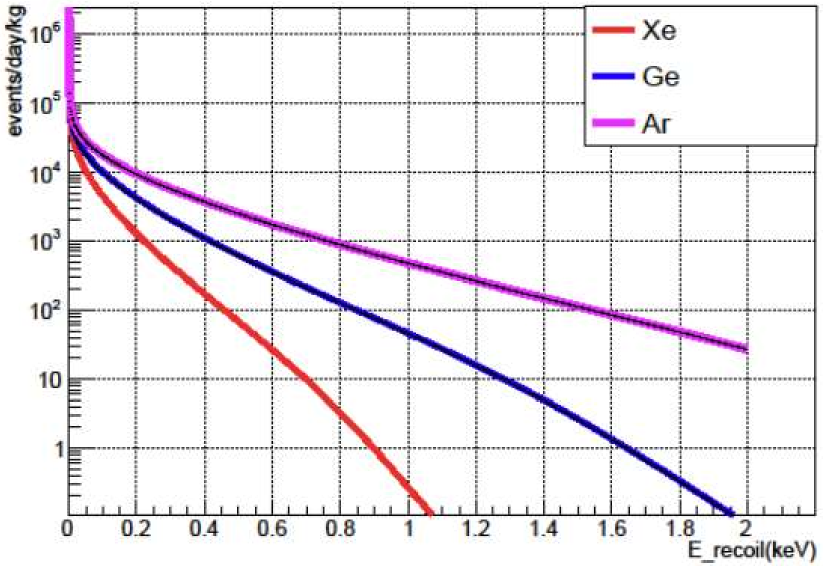


- ➢ **Most of them are based HPGe**
- ➢ **The Dual Phase Argon Detector are developing for the same purpose**

The Dual Phase Argon Detector for Reactor CEνNS Measurement

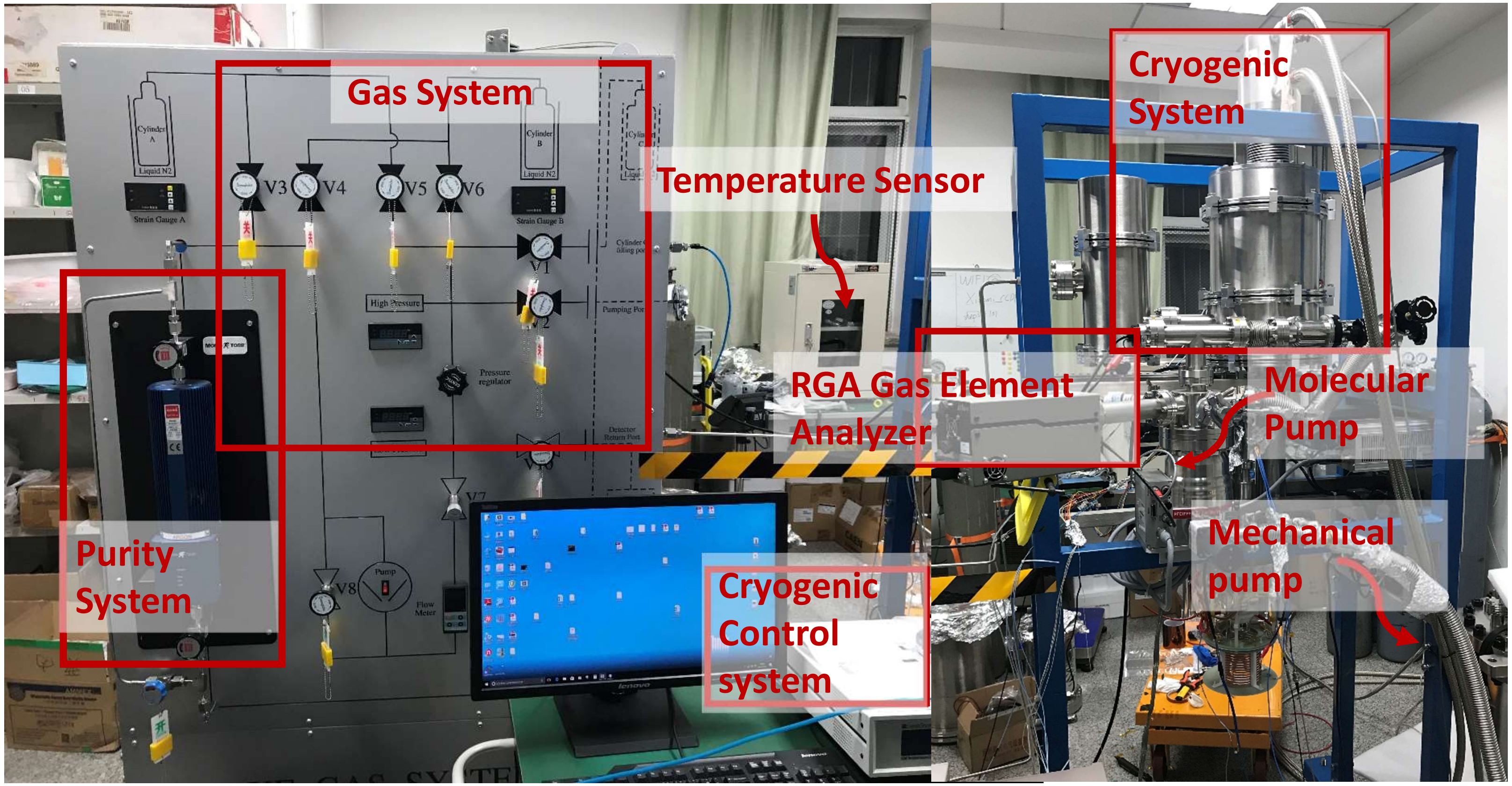


- ➢Easy for Larger Volume
- ➢Low threshold ~0.1keV
- ➢SiPM readout with low radio purity and high PE
- ➢Only read S2 to reach low threshold



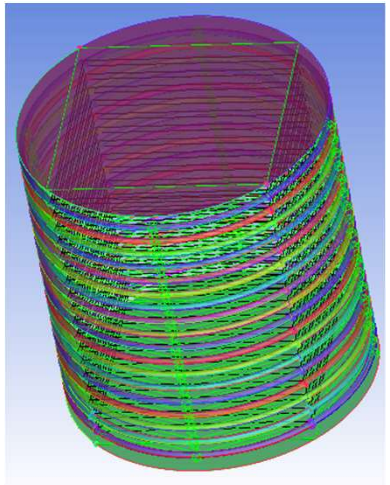
The Prototype of Dual Phase Detector

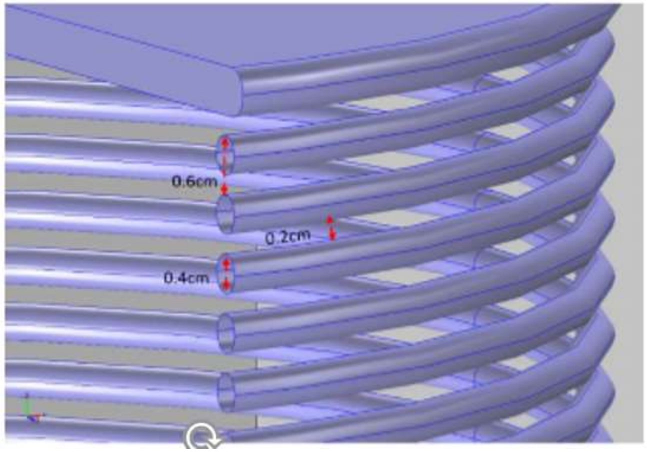
- Based on the Dual Phase Detector at IHEP,
- Original design for Xeon,
- But we used for Argon test to study some key technology.

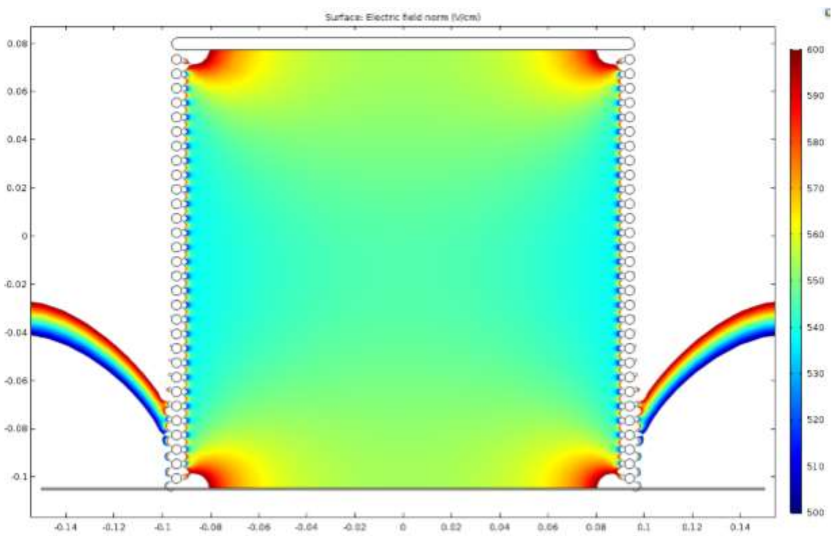


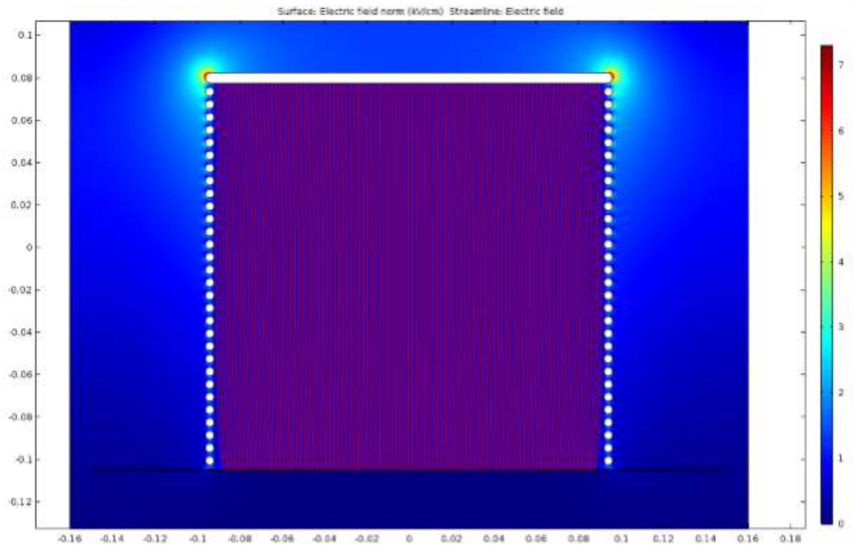
The Electric Field Simulation

Shaping Ring Numbers： 16
Gas Gap： 8mm
Liquid Gap： 106mm
Outer Diameter： 180mm
Inside Diameter： 90mm

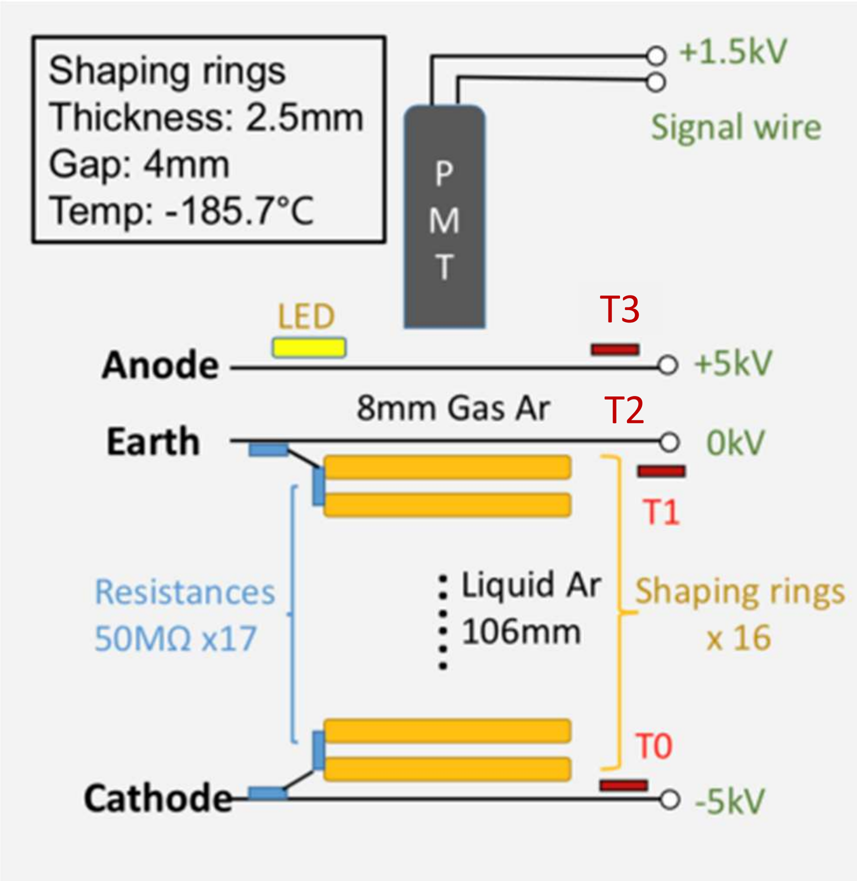


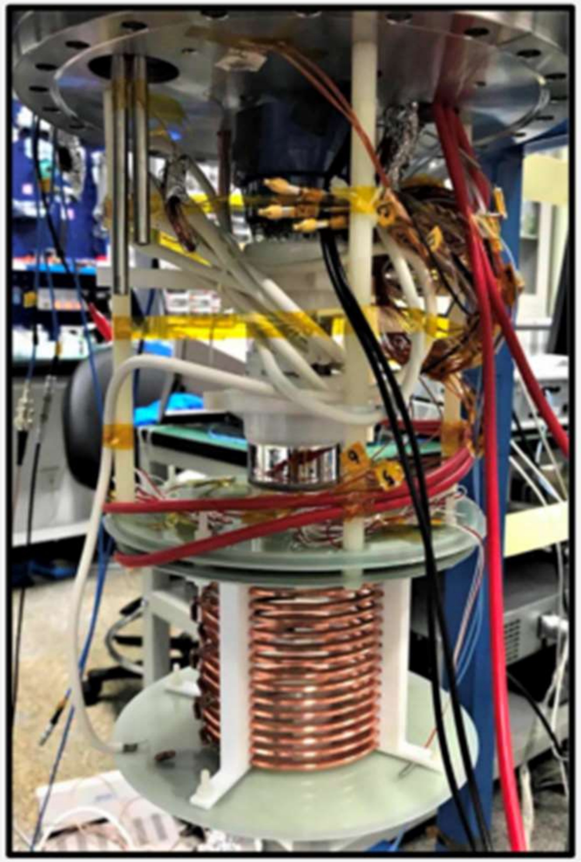


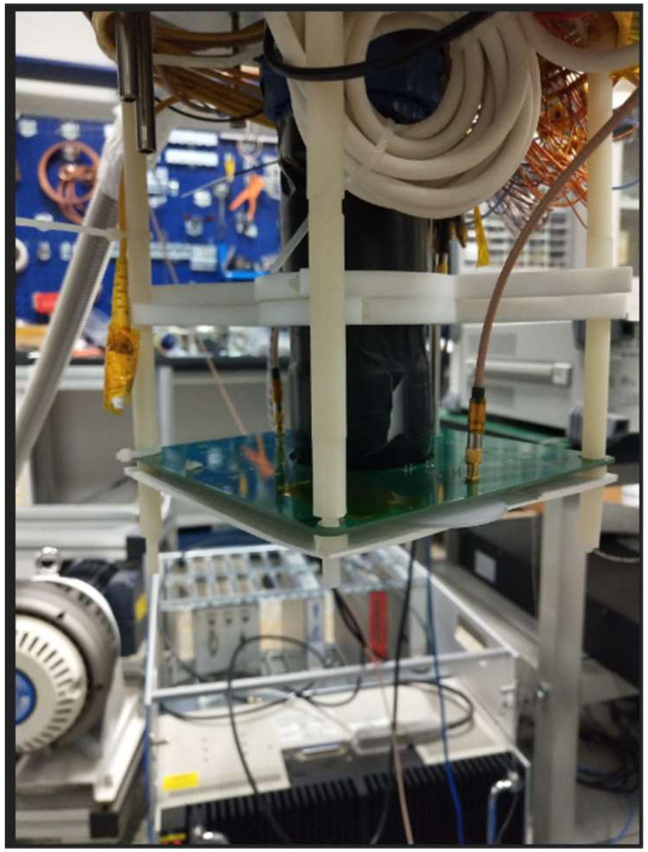




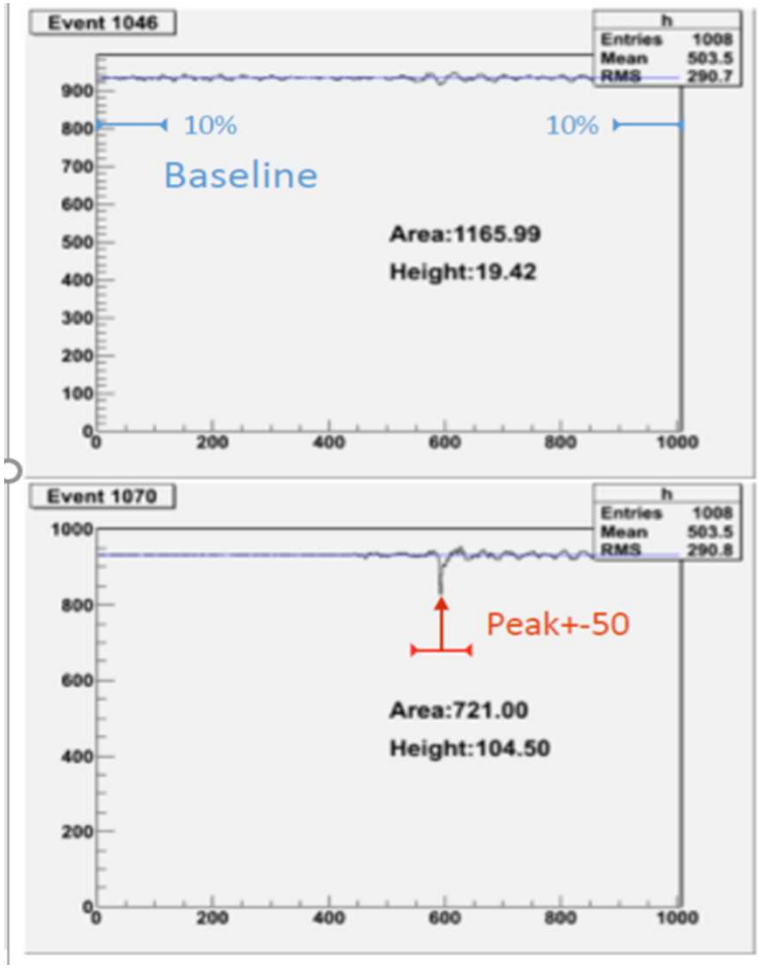
The Structure of TPC

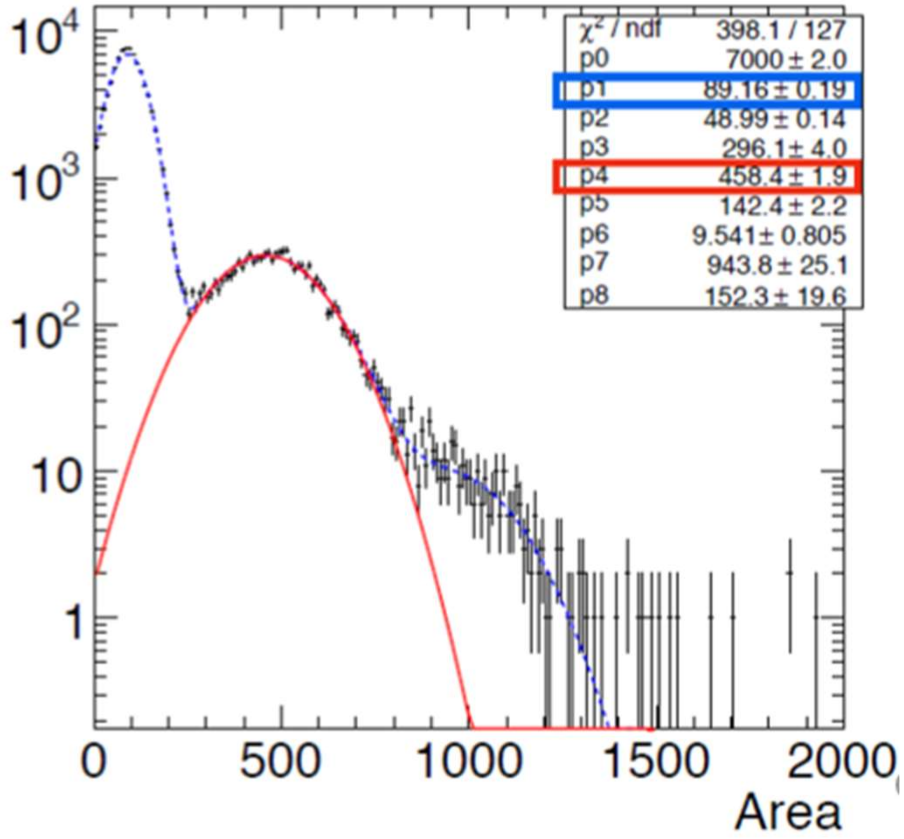




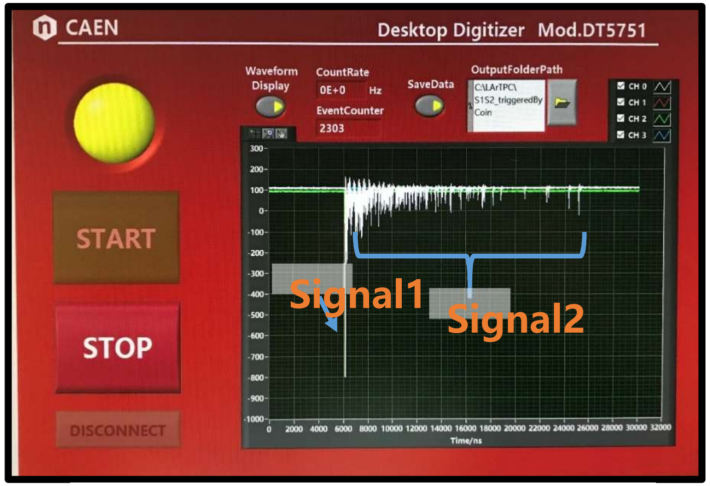


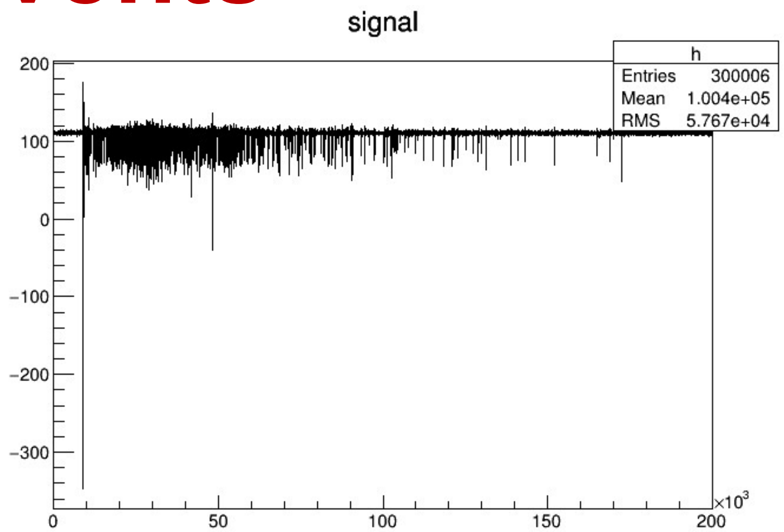
The LED Calibration

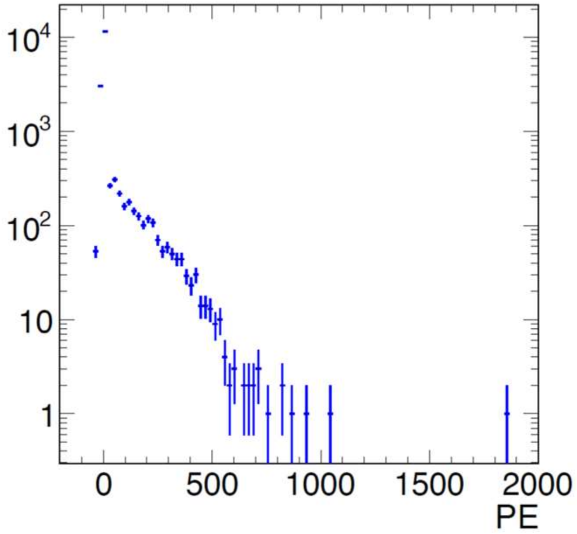


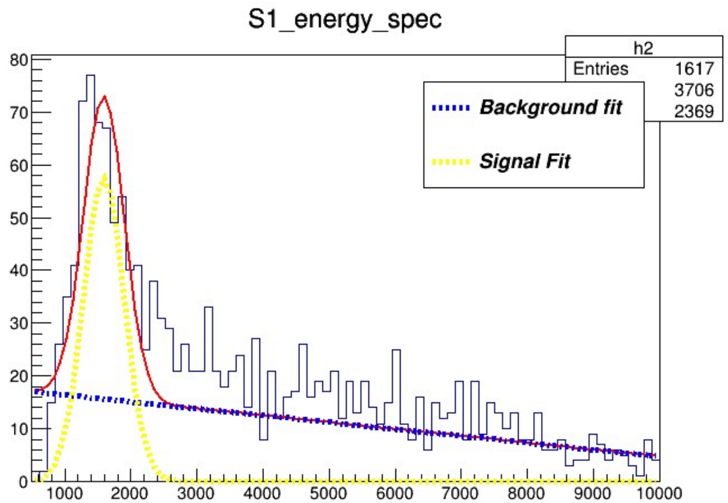


The Muon Events









The Development of Cold Readout for SiPM

	PMT	SiPM
Maximum PDE	10~40%	30~60%
Gain	10^5~10^7	10^5~10^7
Operating Voltage	~kV	<100V
Dark noise(room T)	1~50kHz	~50kHz/mm^2
Correlated noise rate	Low(<~10%)	High(10~60%)
Capacitance	~10pF	~20pF/mm^2
Radio purity	Bad	Good

Many readout options, many ASICs
Trying to chose 2~3 of them to develop

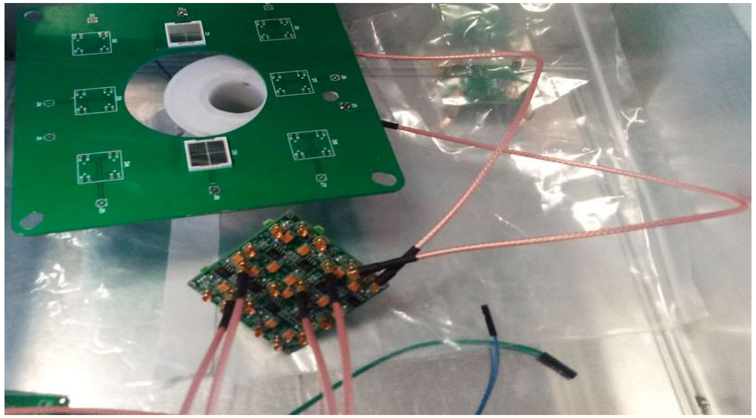
➢ nEXO pre-amplifier

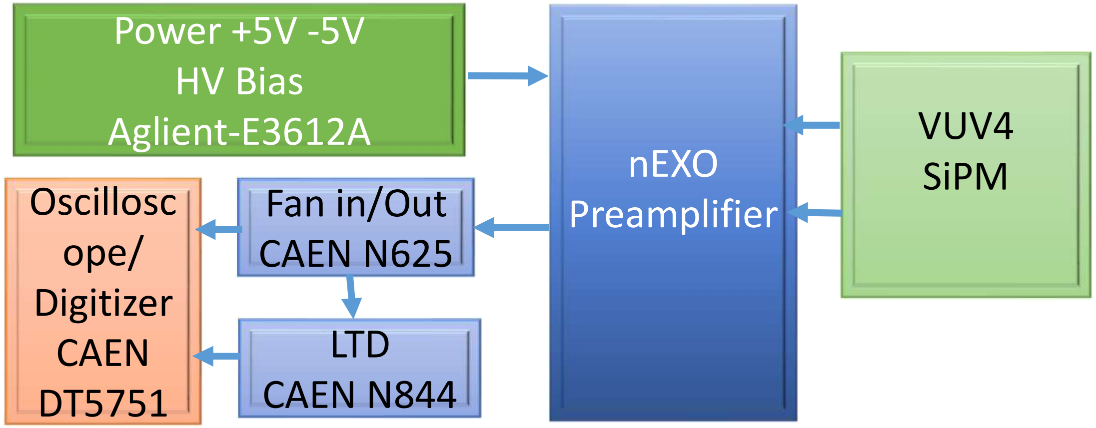
- Concrete components, the ASIC is under design.
- Developed for cold electronics (-104 degree)
- Has been tested by nEXO

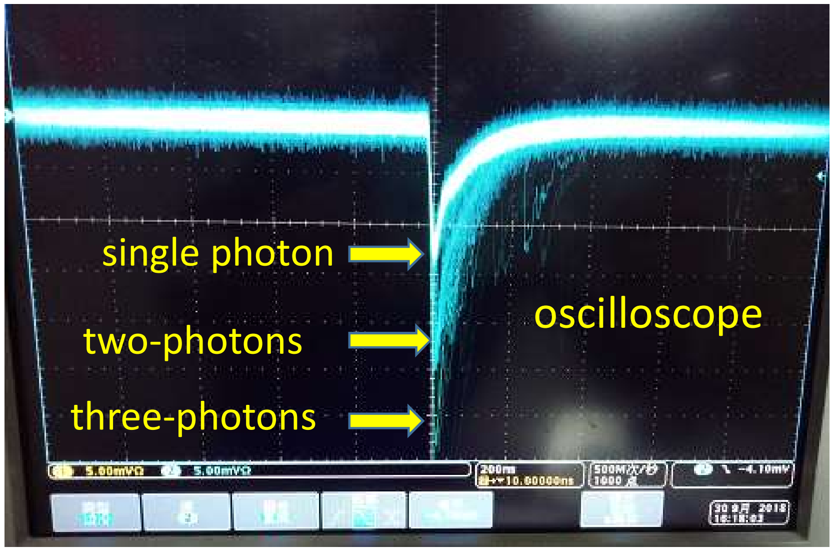
➢ Another 2 cold pre-amplifier

One suggestions from Darkside
Another one from INFN

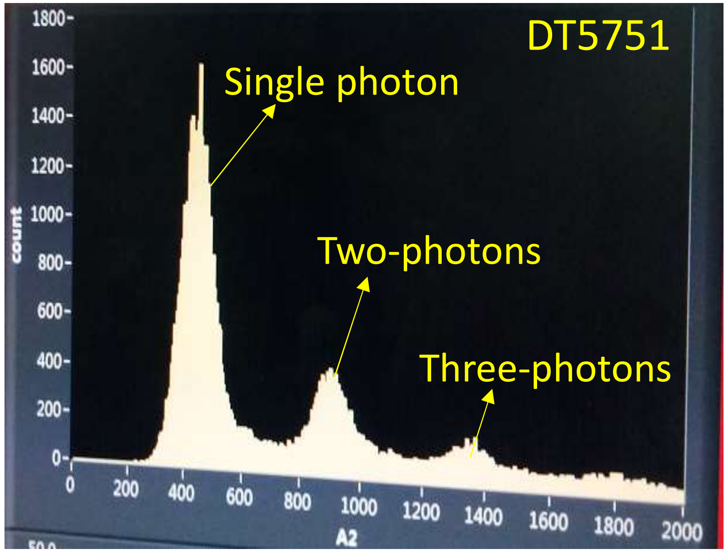
LAB test of nEXO Cold Readout





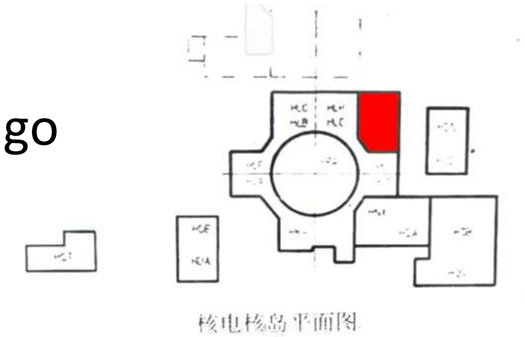


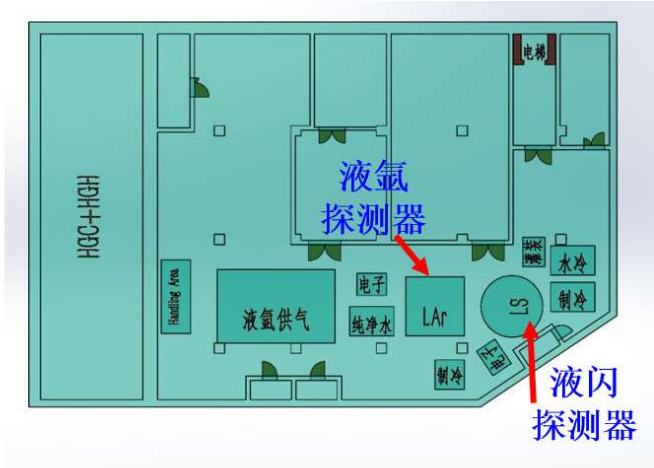
Temperature：215.4K
Over voltage：4.2 V
Readout area：4 VUV4 array

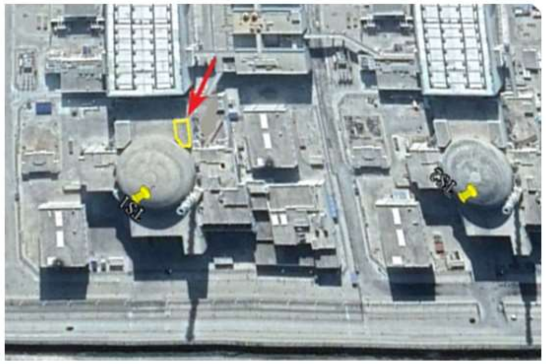


The TaiShan Nuclear Power Plant

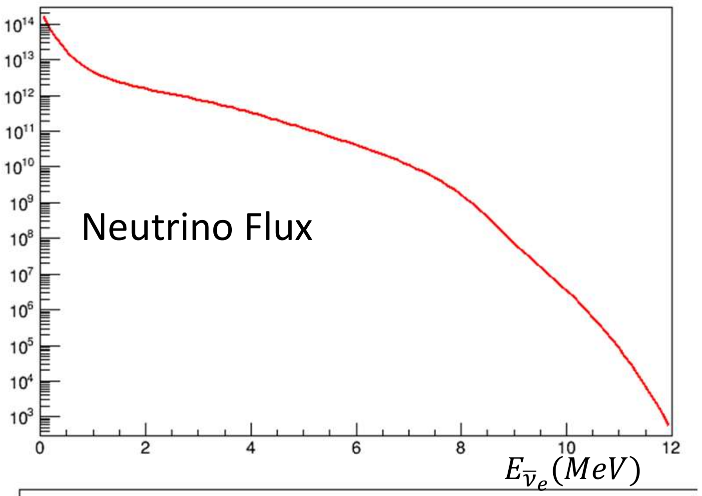
- **4.6 GW,** started operation 4 months ago
- Spacious room at 10 m underground, **~30m horizontally from core**
- Access by elevator 1.4x1.8 m

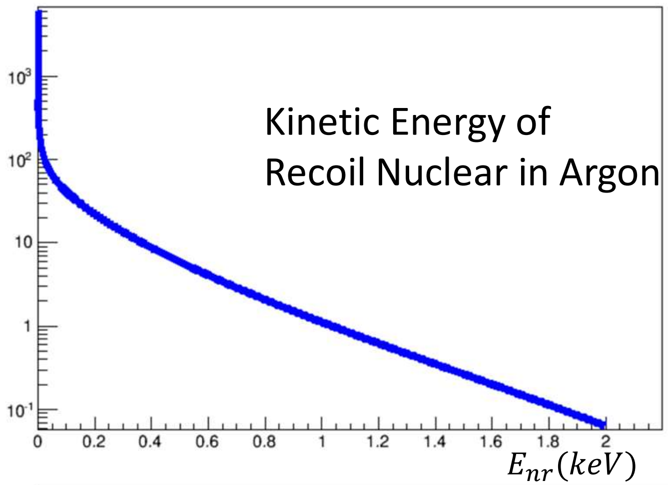


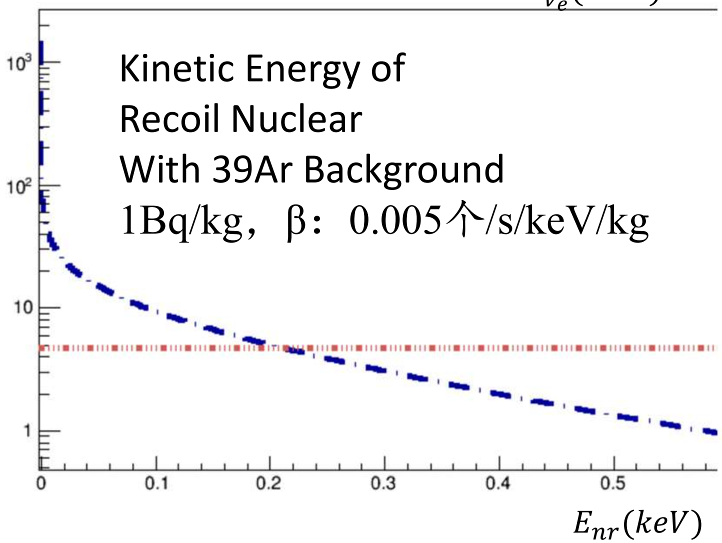


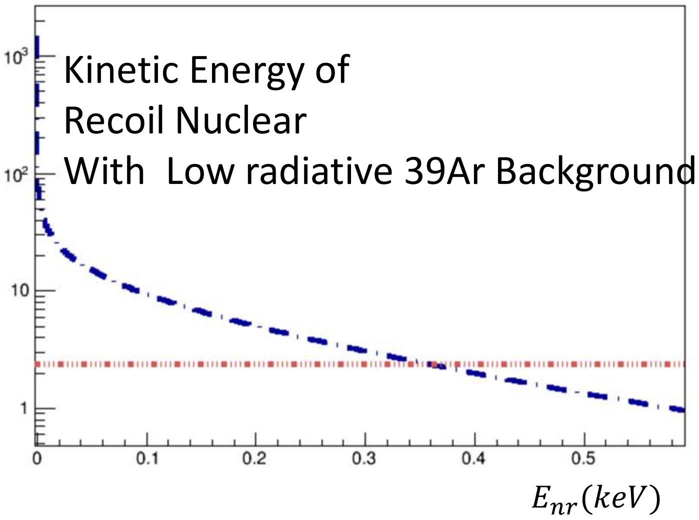


The Expected Events









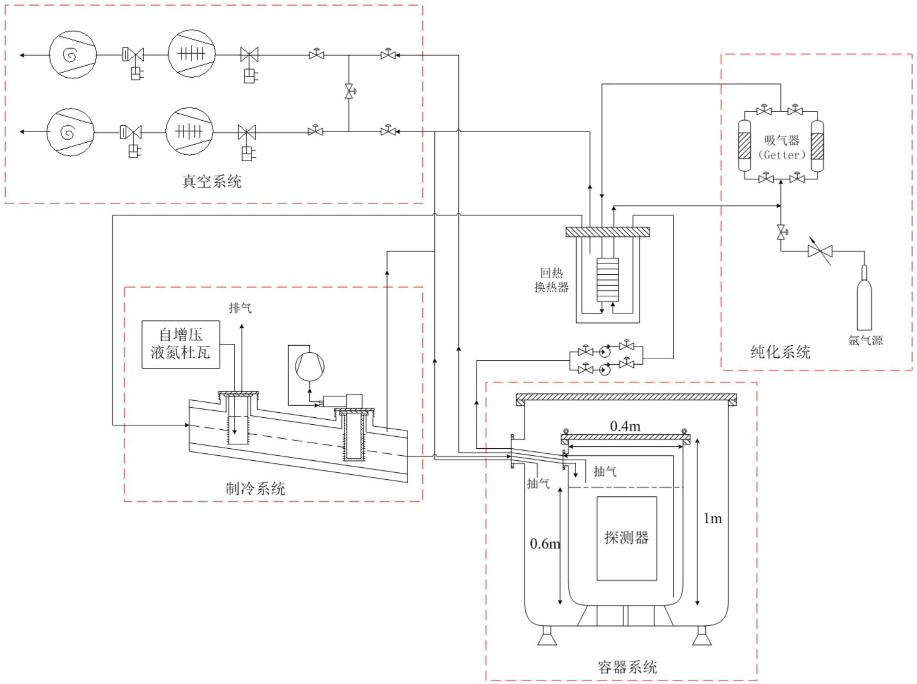
- ✓ **Thermal Power is 4.6 GW**
- ✓ **Distance to the core 31m**
- ✓ **Average flux ~$4.66 \times 10^{13} cm^{-2} s^{-1}$**
- ✓ The expected events per day:

Threshold	Events/day (Nr)	Events/day (ee)
0keV	14549	3323
0.1keV	4146	947
0.2keV	2638	602
0.3keV	1776	406
0.4keV	1232	282

Low threshold to reach 0.1keV

The Planned Dual-phase Argon Detector Design

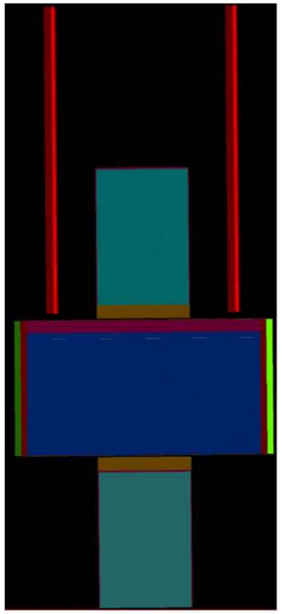
- ✓ FV: 100kg~300kg (not final decided)
- ✓ Low threshold: 0.1keV
- ✓ S2 light readout to reach low threshold
- ✓ SiPM instead PMT for low radiative
- ✓ Low radiative material: Acrylic instead stainless like DEAP-3600

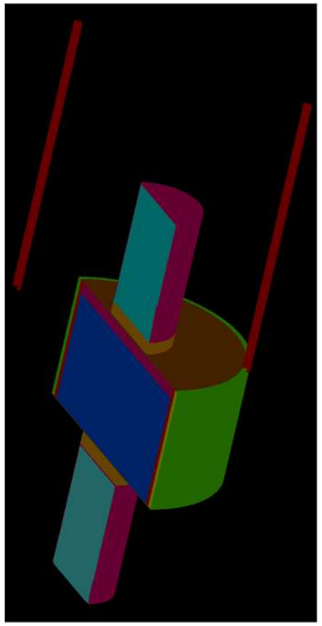


Simple Geant4+NEST Simulation

			USE SPREADSHEET FOR MEAI		
NEST v1.C	NUCLEAR RECOIL				
rho [g/cc	dft [V/cm]	T-I param	keVnr	epsilon	'k' facto
2.9	500	3.77E-02	1.00	0.001043	0.139244
2.9	500	3.77E-02	2.00	0.002087	0.139244
2.9	660	3.71E-02	0.15	0.000157	0.139244

"g1" or "alpha1"		"g2" or "alpha2"		(extraction efficiency x SE		
S1 gain	S1 [PE]	S2 gain	S2 [PE]	keVee True	A(tomic)	Number
0.1	0.19088	20	153.64	0.1311107	131	
0.1	0.662218	20	288.5785	0.2879658	131	
0.1	0.004138	20	21.41433	0.0151991	131	





- The length of gas gap and liquid gap
- Simulation the Electric Field
- Electron recombination probability and electron drift time
- Photoelectric efficiency of SiPM
- The detectable S1 light and S2 light.

Summary and Next Steps

Summary:

- Dual-Phase Argon Detector for reactor CEνNS process in TaiShan Power Plant
- Some primary study did based on Dual-Phase Detector system
- The cold pre-amplifier for SiPM
- Only S2 signal will be read to reach 0.1keV threshold
- Acrylic instead stainless

The R&D just start, welcome join us...

Next Steps:

- The background analysis and Shielding System design
- The detailed technique design for TPC
- The Development for Cold readout system for SiPM
- .....